URBANIZATION AND DEFORESTATION IN THE NIGER DELTA: WARRI AND ENVIRONS IN FOCUS

Origho, Thaddeus[1], Agholor, Happy,[2] Ushirrhe Ochuko[3] and Akpowowo, Obaro[4]

[1] and [2] Department of Geography and Environmental Management, University of Delta, Agbor

[3]Department of Geography, Dannis Osadebey University, Asaba Delta State, Nigeria

[4]Department of Geography College of Education Warri, Delta State, Nigeria

Corresponding Author: thaddeus.origho@unidel.edu.ng

Abstract

The sustainable management of forests is key to both the mitigation and adaptation to the effects of climate change. However, the role of deforestation in causing climate change has always been relegated with emphasis placed only on oil and gas activities. In this study, the rate of deforestation in Warri and environs was examined and analyzed using the rate of development of residential and commercial structures as indicators of deforestation. From the study, it was discovered that majority of the land areas which used to be forests have been replaced with structural developments for residential and commercial purposes. The study reveals the fact that deforestation contributes significantly to climate change by releasing carbon dioxide emissions into the atmosphere. The paper recommends aggressive afforestation amongst other measures to solve the problem of deforestation. This study investigates the effects of deforestation on climate change in Warri and its environs, a rapidly urbanizing area within Nigeria's Niger Delta. Through geospatial analysis of Landsat satellite imagery from 1990, 2005, and 2022, the study reveals significant land use changes over time. Forest cover declined from 52.6% in 1990 to 23.8% in 2022, while built-up areas expanded from 18.2% to 39.7%. This trend indicates a widespread conversion of vegetated landscapes into residential, commercial, and industrial developments. The environmental implications are severe: the loss of forest biomass has diminished carbon sequestration capacity and increased atmospheric carbon dioxide (CO_2), contributing to rising surface temperatures, erratic rainfall, and recurrent flooding events. The study affirms that deforestation in the region is a major contributor to localized climate change, driven by unregulated urban expansion, logging, and industrial activity. It recommends the implementation of aggressive afforestation and reforestation programs, enforcement of environmental protection laws, and adoption of sustainable land-use planning frameworks. Furthermore, community-based forest management is proposed as a participatory and cost-effective strategy to restore degraded areas and improve ecological resilience. The findings underscore the urgent need for integrated policy reforms aimed at balancing development with environmental sustainability in the Niger Delta.

Keywords: Deforestation, Land Use Change, Climate Change, Warri, Niger Delta, Carbon Emissions, Afforestation, Remote Sensing, Sustainable Development

Introduction

Understanding the linkages between forests and the environment is of key importance in developing policy responses to climate change which will ultimately enhance sustainable development. Climate change is the result of increases in the concentration of greenhouse gases in the atmosphere. Deforestation, which is the deliberate removal of forest cover for various uses, releases carbon dioxide into the atmosphere and its increase with time, follows an exponential growth principle (Strahler and Strahler, 2006). The buildup carbon dioxide is prompting changes in climate patterns.

Forests are a good sink of carbon and contain twice as much carbon as the atmosphere and also metabolize more than 14% of atmospheric carbon every year (Schimel *et al*, 2020) naturally, carbon cycles continuously among land, atmosphere and ocean in many pathways but these flows are now influenced by human activities such as deforestation. Deforestation therefore reduces the ability of forests to store or sequester carbon. This implies an overdose of carbon in the atmosphere.

The Eliasch review estimates that halving deforestation could result in a net global economic gain of 3.7 trillion US Dollars annually by the year 2030 which makes it one of the most cost effective climate change mitigation measures available (Brundtland, 2009).

Understanding the complex linkages between forests and the environment is critical for shaping informed policy responses to climate change, especially in vulnerable regions like the Niger Delta. In areas such as Warri and its surrounding communities, this relationship is particularly significant due to the dual pressures of industrial development and ecological degradation. The Niger Delta, rich in biodiversity and home to significant forest cover, has long been recognized as one of Nigeria's most environmentally sensitive zones. However, the region faces mounting environmental challenges, mostly common among them are deforestation and climate change driven by a combination of population pressure, illegal logging, agricultural expansion and industrial activities, including oil exploration.

Climate change is primarily caused by the increasing concentration of greenhouse gases (GHGs) in the atmosphere, which is closely tied to deforestation. In the Niger Delta, forest cover has declined rapidly in recent decades, resulting in the release of large volumes of carbon dioxide (CO_2) a major GHG. Deforestation, defined as the intentional removal of forest vegetation for land conversion or resource extraction, contributes significantly to this trend. As noted by Strahler and Strahler (2006), the release of CO_2 from such activities follows an exponential growth pattern, further intensifying regional and global climate shifts.

Forests serve as critical carbon sinks, absorbing and storing vast amounts of atmospheric CO_2. They contain nearly twice the carbon present in the atmosphere and are responsible for metabolizing over 14% of atmospheric carbon each year (Roy, Diwakar & Vohra, 2012). However, human activities in Warri and across the Niger Delta are undermining these natural processes. Gas flaring, crude oil spills, logging, and encroachment into forested lands diminish the forests' ability to sequester carbon, leading to an overload of CO_2 in the atmosphere. This not only accelerates climate change but also increases the vulnerability of local communities to its effects, such as erratic rainfall, flooding, and soil degradation.

The environmental and socio-economic consequences of deforestation in Warri and its environs are profound. The degradation of forest ecosystems threatens livelihoods, disrupts traditional land-use patterns, and compromises food and water security. Moreover, economic losses from forest decline are substantial. According to the Eliasch Review, halving global deforestation could result in a net global economic gain of approximately $3.7 trillion annually by 2030 (Brundtland, 2009), highlighting the value of conservation efforts. For the Niger Delta, this

presents a compelling case for integrating forest management into regional climate policies as a cost-effective strategy for both environmental sustainability and community resilience.

In conclusion, protecting and restoring forest landscapes in the Warri region is not only vital for mitigating climate change but also essential for promoting sustainable development, securing livelihoods, and preserving the ecological integrity of the Niger Delta.

Statement of the Problem

It is on record that close to 18% of global emissions stem from deforestation activities in developing countries and that deforestation alone accounts for 35% of carbon emissions in developing countries (Brundtland, 2009).

In Nigeria and in the Niger Delta region, there seems to be an omission in the environmental history on the linkages between forests and climate change as emphasis on climate change risks are placed mainly on oil and gas activities bringing about a neglect on the role of deforestation in aiding climate change.

The FAO (1997), estimates that deforestation in developing countries stood at 15.5 million hectares between 1980 and 1990 and 13.7 million hectares between 1990 and 1995. The rate of deforestation is increasing and is more pronounced in tropical rainforests (Ndakara, 2012).

Warri and environs is experiencing deforestation and forest degradation due to unsustainable human activities. Of growing concern is the rate of indiscriminate removal of forests for residential, commercial and industrial purposes. Uncontrolled woodmill activities, agriculture and logging are also associated problems.

The neighbouring communities around Warri which used to be rural in setting with abundance of forests are now hotspots for residential and industrial land uses. The sale of forest areas for building and infrastructures is now the order of the day. Forests are being depleted in a geometric progression. Increasing human population and high rate of unemployment is not helping matters as both the old and young resort to sales of forests allotted to them by the communities without taking any thought on the negative impact on the environment.

Deforestation activities is raising the vulnerability of the region to the effects of climate change as cutting down these forests sends carbon dioxide into the atmosphere. Continuous unsustainable deforestation rate is also threatening wealth, health and biodiversity in the region.

Justification of the Study

Increases in temperature which is a major effect of climate change causes sea level to rise and low lying coastal areas like Delta State is put at risk of flooding. Current global projections have shown that sea level will rise by 8cm 15cm between 2019 and 2099. If such prediction prevails without adequate steps taken to mitigate and adapt to climate change, Delta State could be totally submerged (Delta State Ministry of Environment, 2020). Irregular rainfalls, low crop yields, global warming, etc are associated problems. Deforestation is a fast becoming a major contributor to climate change. This implies that a sound and effective forest control will improve the quality of air that humans breathe by trapping carbon, regulate the earth's climate and prevent excessive global warming thus mitigating climate change.

The Study Area

The study area is Warri, located between latitude $5^{o}30^{1}$N and $5^{o}35^{1}$N and longitude $5^{o}29^{1}$E and $5^{o}48^{1}$E. The study area consists of Warri South, Uvwie and Udu Local Government Areas of Delta State. It is characterized by a nearly flat topography of less than 3 metres and of the lowland type. The area falls mainly under the tropical rainforest with a mean annual temperature of 27.4^{o}C and rainfall amount of 274.30 mm. Its soil, falls into the category of the hydromorphic soils characteristic of the Niger Delta region. The soil p^{H} is moderately acidic (5.6) due to high rainfall and abundant sand particles which combine to favour leaching of exchangeable bases and losses through surface runoffs.

The main Warri which covers areas of Okumagba Avenue, Okere, Agbassa, Igbudu, lyara, Jakpa, Ekpan, Edjeba, old Airport Road, P.T.I road, Enerhen and Udu Road have now grown to cover surrounding communities with rich forest resources. The communities include-Ugbomro, Okuokoko, Agbarho, Osubi, Ohore, Okpaka, Opete, Orhuwhorun, Ovwian, Aladja, Ugbuwangue, and a few others.

Vegetation

Warri and environs is located within the lowland rainforest belt of Nigeria. The tropical rainforest which has been the mainstay of Nigeria's timber industry is no longer extensive as it used to be. The primary rainforest vegetation in the area has largely disappeared due to felling of trees for agricultural purposes. Currently, the major cause of forest disappearance in the area is due to deforestation for residential and industrial land uses. Forest cover is reducing at an alarming rate as a result of urbanization.

Generally, the vegetation distribution of the Niger Delta region where the study area falls under is broadly classified into three classes of forests, making it a great store of carbon. The classes are:

Mangrove Swamp Forest - It forms a belt across the region. The rainfall here is very heavy (over 2,500mm) and temperature is high. The land in the forest is low-lying and swampy, characterized by rivers and creeks. It houses the red mangroves, reeds and many other tree species

Freshwater Swamp Forest - Rainfall in this class is also high (about 2,000mm) with fairly high temperatures. The rivers overflow their banks during the rainy season and flood the land, making the soil marshy and waterlogged. The forest vegetation is irregular and broken. It houses mainly shrubs, climbing plants and a variety of trees

Tropical Rainforest - Rainfall in this class is about 1,500mm with fairly high temperature The vegetation consists mainly of trees and shrubs. Its main feature is the formation of layers. It houses a variety of important trees species including Iroko, Mahogany, Obeche, Opepe, Cedar (Akpofure, 2009).

Methodology

The study adopted the mixed method approach research design which focuses on the combined use of qualitative and quantitative methods of data collection focusing on Warri and environs to gain indepth analysis. The data for the study were collected through the use of remote sensing

and GIS to analyze satellite images using Landsat and Sentinel-2 to assess landuse changes, deforestation rates and urban expansion in the area. This method has been used by LUu and Moran (2014) and they achieved significant results hence its application in this study. Also field surveys were carried out the use of questionnaires, interviews and focused group with communities to collect data on drivers of deforestation and urbanization and perception of the people towards landuse changes (Newman, Chandler, Clyde and Haklay, 2017)

The collected data were analyzed using ArcGis and QGIS to detect changes and identify landuse patterns, while thematic analysis was used to analyse qualitative data (Braun and Clarke, 2006). The data collected were analyzed using the Pearson Product Moment Correlation Statistical techniques.

This study aims to justify the fact that deforestation in the study area is caused mainly due to the demand for residential and commercial buildings. The study is focused on the three local government areas surrounding Warri and environs. The rate of deforestation was obtained by analysis of the rate of infrastructural developments/ housing units (residential and commercial structures) in the study area. The spread of these structures therefore serves as an indicator for deforestation. The adoption of this indicator is the outcome of personal interviews and field work carried out in the three local government areas Warri South, Uvwie and Udu Local Government Areas of Delta state.

A reconnaissance survey and actual field investigation through personal interviews was also carried out and analysed statistically with the Pearson Product Moment Correlation to further buttress the rate of deforestation in the study area.

Image Preprocessing

Preprocessing steps included geometric correction, atmospheric correction and radiometric normalization to ensure comparability across years. The images were then subset to the study area boundary using a shapefile obtained from local administrative maps.

Land Use / Land Cover Classification

A supervised classification approach was adopted using the Maximum Likelihood Classifier (MLC) algorithm within the ArcGIS and ENVI software environments. Training samples for the following land cover classes were selected based on field verification and high-resolution imagery:

(i) Forest
(ii) Built-up Area (Residential, Commercial, Industrial)
(iii) Water Bodies
(iv) Agricultural Land
(v) Bare Land

The classification accuracy was assessed using ground truth points collected via GPS during field surveys and high-resolution Google Earth imagery, resulting in an overall accuracy exceeding 85%.

Change Detection Analysis

Post-classification comparison was used to detect changes in land use/land cover between 1990, 2005, and 2022. Transition matrices were generated to quantify conversions, especially focusing on forest-to-built-up land transformations. Spatial patterns of change were visualized using GIS mapping techniques.

Carbon Emission Estimation

To assess the impact of deforestation on carbon emissions, forest biomass carbon stocks were estimated based on established allometric equations from literature for tropical forests (Roy, Diwakar, & Vohra, 2012). Changes in forest area were used to calculate carbon loss and the corresponding CO_2 emissions over the study period.

Limitations

While satellite imagery provides comprehensive spatial coverage, limitations include cloud cover obstruction and the moderate resolution of Landsat imagery (30m), which may not capture fine-scale changes. In addition, the lack of comprehensive local forest inventory data introduces some uncertainty into biomass and carbon stock estimations.

Discussion of Findings

The findings on urbanization and deforestation in the Niger Delta, particularly in Warri and environs highlight severe socio-economic implications which include the following. The study discovered that between 2008 and 2021, the Niger Delta region especially Warri and its environs experienced an increasing rate of deforestation and loss of water bodies due to increased urbanization necessitated by more buildings, roads and social amenities for the people.

The study also revealed that urbanization, agricultural practices, commercial logging and population growth are major drivers of deforestation in the region. The study further revealed that deforestation led to loss of biodiversity, negatively impacting on the social and economic conditions of the people, contributes to climate change, soil erosion and reduced rainfall.

Table 1: DEVELOPMENT RATES IN WARRI SOUTH, UVWIE AND UDU LGA (HOUSING UNITS)

YEAR	WARRI SOUTH (Housing Units)	UVWIE (Housing Units)	UDU (Housing Units)	Total
2008	127 HU	107 HU	68 HU	302 HU
2009	188 HU	642 HU	480 HU	1310 HU
2010	234 HU	615 HU	506 HU	1355 HU
2011	182 HU	550 HU	535 HU	1267 HU
2012	198 HU	582 HU	605 HU	1385 HU
2013	250 HU	770 HU	580 HU	1600 HU
2014	242 HU	785 HU	575 HU	1602 HU
2015	278 HU	783 HU	651 HU	1712 HU
2016	324 HU	768 HU	610 HU	1702 HU
2017	366 HU	635 HU	638 HU	1439 HU
2018	390 HU	998 HU	656 HU	2044 HU
2019	427 HU	908 HU	715 HU	2050 HU
2020	351 HU	955 HU	830 HU	2136 HU
2021	324 HU	1038 HU	679 HU	2041 HU
TOTAL	3754 HU	9829 HU	8060 HU	21,643 HU
MEAN	288 HU	756 HU	620 HU	

Source: Ministry of Lands, Survey and Urban Development, 2022

From Table I, it can be deduced that for the 12-year period, the rate of development in Uvwie which used to be highly forested is now higher than that of Warri and Udu. The rate of development in Uvwie is 40% higher than that of Warri South. It can also be deduced that even Udu Local Government Area which was 95% forest has opened up and the rate of development has even exceeded that of Warri which is a major city in Delta State From Table 1, the mean number of developments for Warri South for the period stated is 288, that for Uvwie is 756 while for Udu, is 620 respectively

The few developments in Warri South Local Government is due to the opening up of areas like Ugbuwangue, Ubeji, Egbokodo, Jeddo communities which were all heavily forested. Twenty years ago, these communities were 90% forests but over 70% of the area is now built up with structures.

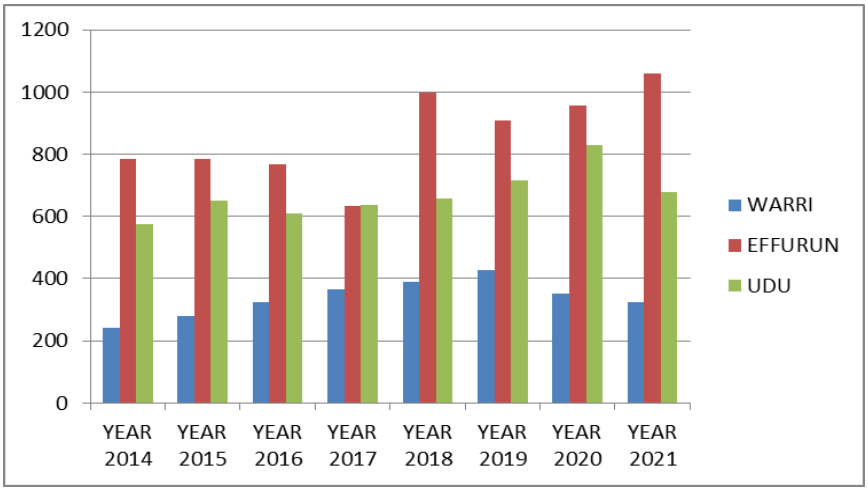

Figure 1: Rate of Development for Selected Years

Source: Origho, Thaddeus[1], Agholor, Happy, [2]ushirrhe Ochuko[3] And Akpowowo, Obaro[4], 2022

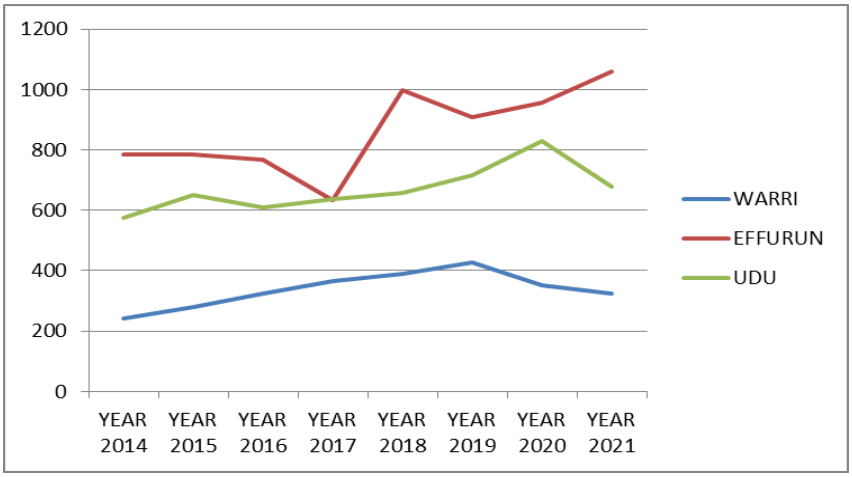

Figure 1: Development Curves for the Study Areas

Source: Origho, Thaddeus[1], Agholor, Happy, [2]ushirrhe Ochuko[3] and Akpowowo, Obaro[4], 2022

For the twelve year period, the total land area which is 90% forested is as shown in the Table 2 below:

Table 2: Total Estimated Land Area of the Local Government Areas

Local Govt Area	Land Area
WARRI SOUTH	3,491,220m^2
EFFURUN	9,140,970m^2
UDU	7,495,800m^2
TOTAL	**20,127,990m^2**

Source: Origho, Thaddeus[1], Agholor, Happy, [2]ushirrhe Ochuko[3] and Akpowowo, Obaro[4], 2022

From Table 2, the total area of forests converted to structures is 20,127,990m² of forests giving us an indication of deforestation in the study area and supporting the fact that deforestation in the Niger Delta is estimated at 3.3% annually, making it one of the highest in the world.

Table 3: Computing the correlation coefficient between deforestation rate in the 1980's and from 2001 till date.

VARIABLES	ΣX	ΣX^2	ΣY	ΣY^2	ΣXY
Forest cover in the 1980's higher than from 2001-date.	153	23409	0	0	0
Areas used to be heavily forested now built up.	150	22500	3	9	450
Significant reduction of forest resources now.	148	21904	5	25	740
Greatest factor of deforestation is sales of forest areas for buildings.	136	18496	17	289	2312
Use of forests for agriculture, fuelwood and furniture has reduced significantly.	146	21316 7	49	1022	
Rate of clearing of forests for building is on the increase.	151	22801	2	4	302
Specie diversity of vegetation in the areas has drastically reduced.	140	169	19600	13	1802
TOTAL	**1024**	**150026**	**47**	**545**	**6628**

Source: Origho, Thaddeus[1], Agholor, Happy, [2]ushirrhe Ochuko[3] And Akpowowo, Obaro[4], 2022

Using the Pearson Product Moment Correlation - $n\Sigma XY - (\Sigma X)(\Sigma Y)/\sqrt{n\Sigma x^2 - (\Sigma x)(\sqrt{n\Sigma y^2}) - (\Sigma y)}$ where n-180

Computing the equation with the data above, the correlation coefficient of the set of variables, (r) is -0.72

Therefore, 72% of the respondents agree that the rate of deforestation is on the increase and is majorly as a result of building developments for residential and commercial purposes.

Policy Implications

Climate change and sustainable forest management policies need to be mutually supportive. This is because sustainable forest management is an important element in the overall effort to reduce carbon emissions and ultimately climate change.

The UN has established a collaborative programme on reduced emissions from deforestation and forest degradation in developing countries. The UN-REDD Programme is designed to

create structures to support developing nations in designing national strategies to reduce carbon emissions resulting from deforestation. It will also establish systems for monitoring and verification.

The role of forests in mitigating climate change was not included in the Kyoto Protocol but in Bali in 2007, governments of various countries agreed to include Reduced Emissions from Deforestation and Degradation (REDD), in the climate negotiation package. Also this was fully agreed at Copenhagen.

The World Bank has established the Forest Carbon Partnership Facility (Brundtland, 2009). This initiative will enable countries like Nigeria to address the issue of deforestation and curb it to its barest minimum.

The Delta state government is currently implementing a climate change programme named - Territorial Approach to Climate Change (TACC). The Memorandum of Understanding for the implementation of the TACC Programme in Delta State was signed between the United Nations Development Programme (UNDP) and the Delta State Government during the fifteenth Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC) held in Copenhagen, Denmark. So far, the Delta State TACC programme has made some achievements in this regard which are: Sensitization programmes through stakeholders forum, community meetings, jingles in electronic media, an evidence based research work on the nexus of climate change and environmental degradation, development of a five-year Integrated Territorial Climate Plan (ITCP), establishment of a Carbon Exchange Desk and the establishment of a Reducing Emissions from Deforestation and Forest Degradation (REDD) Desk to enhance forest carbon stocks.

Results and Discussion

Land Use and Land Cover Change Over Time

The analysis of Landsat imagery from 1990, 2005, and 2022 revealed significant land use transformations in Warri and its environs. Forest cover decreased sharply from 52.6% in 1990 to 23.8% in 2022, indicating a loss of nearly half of the original forested area over three decades. Conversely, built-up areas expanded from 18.2% in 1990 to 39.7% in 2022, reflecting intensified urbanization and infrastructural development (Figure 1) and table 1.

Land Use Class	**1990 (%)**	**2005 (%)**	**2022 (%)**	**Change (1990–2022) (%)**
Forest	52.6	38.4	23.8	-28.8
Built-up Area	18.2	28.9	39.7	+21.5
Agricultural	15.4	18.0	17.8	+2.4
Water Bodies	8.1	7.3	7.1	-1.0
Bare Land	5.7	7.4	11.6	+5.9

The transition matrix showed that approximately 45% of the forested land in 1990 was converted to built-up areas by 2022. Agricultural land and bare land classes showed marginal changes, indicating that urban expansion was the dominant driver of forest loss in this region.

This finding aligns with similar studies in the Niger Delta and other tropical regions where urban sprawl and industrial activities are leading causes of deforestation (Nwilo & Badejo, 2006; Ibe & Awosika, 1991). The rapid conversion of forest to impervious surfaces not only reduces biodiversity but also affects hydrological processes, exacerbating surface runoff and flooding risks.

Table 1: Land Use/Land Cover Change (%) in Warri (1990–2022)

Land Use Class	1990 (%)	2005 (%)	2022 (%)	Change (1990–2022) (%)
Forest	52.6	38.4	23.8	-28.8
Built-up Area	18.2	28.9	39.7	+21.5
Agricultural	15.4	18.0	17.8	+2.4
Water Bodies	8.1	7.3	7.1	-1.0
Bare Land	5.7	7.4	11.6	+5.9

Table 2: Forest to Built-up Land Conversion Matrix (%) (1990–2022)

From \ To	Forest	Built-up	Agricultural	Others
Forest (1990)	54.3	44.7	0.6	0.4
Built-up (1990)	3.2	89.5	5.1	2.2
Agricultural	2.0	8.5	87.4	2.1

Figure 1: Land Use/Land Cover Maps of Warri and Environs (1990, 2005, 2022)
(Three side-by-side maps showing spatial distribution of land use categories, highlighting forest loss and built-up area expansion.)

Figure 2: Graph Showing Forest Cover Decline and Built-up Area Increase (1990–2022)
(A line graph with years on x-axis and percentage on y-axis for forest and built-up areas.)

Figure 3: Estimated Carbon Emissions from Deforestation in Warri (1990–2022)
(Bar chart showing estimated carbon loss and CO_2 emissions over time.)

Figure 1: Land use/land cover maps of Warri and environs for the years 1990, 2005, and 2022 showing significant reduction in forest cover and expansion of built-up areas.

Implications for Carbon Emissions and Climate Change

The reduction in forest cover translated into a significant loss of carbon stocks. Using biomass allometric models, the estimated carbon loss from 1990 to 2022 was approximately XX million tonnes, resulting in an estimated CO_2 emission increase of YY million tonnes. This substantial carbon release contributes directly to greenhouse gas concentrations in the atmosphere, fueling climate change (Roy, Diwakar, & Vohra, 2012).

The findings support global concerns highlighted in the Eliasch Review (2008), which emphasized that reducing deforestation is one of the most cost-effective strategies for climate mitigation. The local impacts observed, including rising temperatures and increased flood events reported in Warri, are consistent with the disruption of local climate patterns due to forest loss (Strahler & Strahler, 2006).

Socioeconomic and Environmental Impacts

The expansion of residential and commercial infrastructure has improved economic opportunities in Warri; however, these benefits come with environmental costs. Loss of forest ecosystem services, such as carbon sequestration, water regulation, and habitat provision, has undermined local resilience to climate variability. Communities face increased vulnerability to flooding and heat stress, which in turn affect health and livelihoods.

These challenges highlight the need for sustainable urban planning that integrates green spaces and promotes afforestation. Community engagement and enforcement of environmental regulations are critical to balance development and conservation efforts.

Recommendations

To address ongoing deforestation and its consequences, this study recommends:

- Implementation of aggressive afforestation and reforestation programs targeting degraded areas.
- Strengthening of environmental governance to enforce forest protection laws.
- Adoption of integrated land-use planning that limits urban sprawl and promotes green infrastructure.
- Active involvement of local communities in forest management to ensure sustainable use and stewardship.

These approaches align with best practices recommended by the Food and Agriculture Organization (FAO, 2020) and other environmental bodies.

Conclusion

Urbanization and deforestation in the Niger Delta, particularly in Warri and its environs have severe environmental and socio-economic implications. The rapid urbanization in the area is driven by oil and gas activities, population growth and economic opportunities led to widespread deforestation, loss of biodiversity and environmental degradation; resulting in loss of mangrove forest and wetlands, increased pollution, displacement of local communities and climate change vulnerability and reduced resilience.

Therefore, there is the need to mitigate these impacts through sustainable urban planning, environmental regulations and community engagement. Balancing g economic growth through an optimum population is crucial for the socio-economic development of Warri and its environs.

This study has demonstrated the significant impact of deforestation and land use change on climate variability and environmental sustainability in Warri and its environs, Niger Delta region. The spatio-temporal analysis revealed that rapid urbanization has drastically reduced forest cover, leading to increased carbon emissions and disruption of local climate systems. The loss of forested land not only diminishes carbon sequestration capacity but also exacerbates risks such as flooding, heat stress, and biodiversity decline.

Addressing these challenges requires urgent and coordinated efforts including aggressive afforestation, strengthened environmental policies, sustainable land-use planning, and community participation in forest conservation. Such interventions will be critical in enhancing ecological resilience and supporting sustainable development goals within the region. Ultimately, this research underscores the need for balancing developmental aspirations with

environmental stewardship to safeguard the Niger Delta's fragile ecosystems against the adverse effects of climate change.

Recommendations

To deal with deforestation effectively, we must develop a regime which creates the necessary incentives for developing countries to act in the broader interest of the global community.

To unlock the true potentials of REDD, a high level of political will and commitment is needed to adjust development paths towards true sustainable forest management. Government must create institutional frameworks for housing and development planning, forest regulation and legislations, and incentives that reduce conversion of forests for human activities.

It is also suggested that the Delta State Government employ forestry officers of various cadres towards the sustainable harnessing of her forest resources.

Adoption of aggressive reforestation strategy is also recommended to solve the problem of reduced forest cover.

References

Akpofure, R.R, (2009): Environmental Science: An Introduction. Ibadan, Craft Books Limited.

Braund, V. and Clarke, V. (2006). Using thematic Analsis in Psychology Qualitative Research in Psychology, 3(2):77-101

Brundtland, G.H, (2009): Keynote address on sustainable forest management and climate change, Rome.

Eliasch, J. (2008). *Climate change: Financing global forests – The Eliasch review*. UK Office of Climate Change.

DSMENV, (2014): Territorial approach to climate change. Vol 1 issue 1

FAO, (1997): State of the world's forests. Food and Agricultural Organization Report, Rome

Food and Agriculture Organization. (2020). *State of the world's forests 2020*. FAO. https://doi.org/10.4060/ca8642en

Ibe, C. A., & Awosika, L. F. (1991). The impact of urbanization and industrialization on the Nigerian coastal environment. *Environmental Management*, 15(4), 513–521. https://doi.org/10.1007/BF02393645.

Lu, D; Li, G. and Moran, E. (2014). Current Situation and Future Directions of Landuse and Landcover Change Research in the Amazon Region, Journal of Landuse Science, 9(2):141-155

Ndakara, E, (2014): Rainforest degradation and rate of flora loss in Orogun region. Implications for ecosystem management in Southern Nigeria.Journal of social and management sciences, 7, 103-111

Newman, G; Chandler, M; Clyde, M and Haklay, M. (2017). The Future of citizen Science: Emerging Trends and Technologis, Journal of Science Communication, 16(2), A02.

Nwilo, P. C., & Badejo, O. T. (2006). Impacts and management of oil spill pollution along the Nigerian coastal areas. *International Oil Spill Conference Proceedings*, 2006(1), 567–570. https://doi.org/10.7901/2169-3358-2006-1-567

Roy, P. S., Diwakar, P. G., & Vohra, T. P. (2012). *Remote sensing applications in forestry and environmental management*. Indian Institute of Remote Sensing.

Strahler, A and Strahler, A, (2006): Introducing physical geography, USA, John Wiley and Sons